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A DIGITAL SIMULATION MODEL OF MESSAGE HANDLING IN THE TACTICAL OPERATIONS SYSTEM

III. FURTHER EXTENSIONS OF THE MODEL FOR INCREASED INTERACTION

William R. Leahy, Martin R. Lautman, Jon L. Bearde and Arthur I. Siegel
Applied Psychological Services, Inc.

SYSTEMS INTEGRATION AND COMMAND/CONTROL TECHNICAL AREA

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U. S. Army

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PREFACE

The present report is the last in a series of three reports[1,2] which describe the inner workings of MANMODEL--a name which has become associated with our attempt to produce a simulator which would yield measures of system performance under different mixes of equipment, personnel, and procedures. The work has not come to an end. Rather, a mid-point milestone has been reached with the issuing of this report. Consequently, it may be of interest to trace the history of MANMODEL's development. This brief preface will not be the whole story but hopefully will disclose the lessons learned, in order that others can capitalize on the good points and avoid the pitfalls.

MANMODEL began as a by-product from ARI's Field Unit approach toward bridging the gap between the laboratory and the field. The Field Unit approach may be described as follows: you selectively structure a human factors group of personnel who are primarily laboratory oriented, place them on-site as an integral part of the design and evaluation process, and in this manner provide a two-way transducer between research and applications. For this project an ARI Field Unit was formed and co-located in Heidelberg, Germany with personnel from the U.S. Army Computer Systems Command, Headquarters U.S. Army Europe and Seventh Army to provide across-the-board human factors support while the U.S. Army's first automated tactical operations system (TOS) was being evolved in the hands and the setting of the users.

This phase of what is still an ongoing TOS effort took place in 1967-1970. During that period considerable human factors research was conducted, both in the laboratory and the field, to answer the many human factors problems as they arose.[3,4] Before long, it became evident that a framework

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[1] Siegel, A. I., J. J. Wolf, and W. R. Leahy. A digital simulation model of message handling in the tactical operations system: I. The model, its sensitivity, and user's manual. ARI Research Memorandum 73-5, November 1973.

[2] Siegel, A. I., J. J. Wolf, W. R. Leahy, and J. L. Bearde. A digital simulation model of message handling in the tactical operations system: II. Extensions of the model for interactivity with subjects and experimeters. ARI Research Memorandum 73-6, December 1973.

[3] Ringel, S., J. D. Baker, M. H. Strub, and L. L. Kensinger. Human Factors research in command information processing systems--summary of recent studies. ARI Research Study 69-6, May 1969.

[4] Baker, J.D. Acorns in flower pots/psychologists in the field. <u>JSAS Catalog of Selected Documents in Psychology</u>, 1972, <u>2</u>, p.88.

was needed which would link the implications from the human-performance data being generated to system performance. Additionally, TOS was rapidly reaching a point where the design verification evaluation efforts would require the development of a cohesive test plan to integrate all aspects and relationships of the man-machine interface and tie them to the system performance measures. From these efforts the form of the present model began to emerge.

An on-site visit from Professor Bernard Metz of the Centre D'Etudes Bioclimatique in Strasbourg, France, provided the impetus to add substance to the form. In describing our work and how each aspect interrelated, a skeleton of the model was used as a framework for presentation. Professor Metz became very much interested in the concept itself and suggested that the overall idea be further articulated, key points elaborated upon, and the results presented at the Fourth International Congress on Ergonomics. The outcome was the birth of MANMODEL as a model.[5]

But to be valuable as a general-purpose tool in support of ongoing and future Army tactical data system efforts, the model--this representation of reality--needed to be further developed into a simulator. This required that complex logic, structure, and software be developed to produce a simulation vehicle which would combine the effects of such variables as message queuing, detailed message processing procedures, error rates, and personnel characteristics--along with stochastic variations--to yield predictions of system performance. It was decided that the work would be accomplished through contract support; thus began this professionally satisfying and highly productive association with Dr. Arthur Siegel and his colleagues.

The first version of the MANMODEL simulator required card-punch input, used batch processing, and produced hard-copy line-printer output. During the development of this version of the simulator we encountered one of our lessons--if you can aggregate items without significant loss of predictive power, do so, for it will make your model both general and more manageable. The case in point here was that the original error schema developed from MANMODEL [6] was found to be much too specific to a particular system which in itself had some peculiar characteristics. To offset this weakness, a more general error schema was devised.[7]

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[5] Baker, J.D. Quantitative modeling of human performance in information systems, Ergonomics, 1970, 13 (6), 645-664. ARI Technical Paper 232, (AD 746-096).

[6] Baker, 1970, op. cit.

[7] Nawrocki, L. H., M. H. Strub, and R. M. Cecil. Error categorization and analysis in man-computer communication systems, IEEE Transactions on Reliability, Vol. R-22, August 1973.

When Version I became operational it was realized that MANMODEL would be more useful if a designer or researcher were able to sit on-line and pose "What if" questions. Further, the "What if" questions could be successively refined if the results of each run were rapidly summarized and displayed for the user. This modification produced Version II in which: (1) appropriate parameters would be displayed on a CRT for the person using the model; (2) he could manipulate these parameters on-line; (3) he would immediately see displayed a summary of the results of this change on system performance; and (4) hard-copy printouts of the detailed interactions could subsequently be acquired.

At this stage of the development a further extension of the model appeared to be possible.

> A ... benefit inherent in this approach is that it is modular and permits plugging human performance studies directly into a system framework ... (One technique) would be to start up the model with randomly sampled values for the parameters for each node in the data flow and processing dimension ... Into this flow we introduce an on-line human factors study which may have as its basic goal the development of performance measures along the task analysis dimension, but which could be providing simultaneous measures of the perturbations the human is making on system output.[8]

With the knowledge gained in getting Version II of MANMODEL operating, the above idea did not seem too far-fetched. Thus, yet a third version of the model was undertaken. The result was the production of a man-in-the-loop hybrid simulation vehicle which permits the MANMODEL program to operate in the background while being simultaneously responsive to two on-line sources. One source is the experimental subject who is providing his own performance data as inputs; the second is an on-line experimenter/monitor who is providing as input information concerning those activities of the subject which the computer is incapable of sensing. This third version of MANMODEL is the topic of the present report.

The reader should be cautioned that correspondence is not exact between the three versions of MANMODEL and the three reports describing it. For example, portions of Version III are described in Volume II of this series.

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[8] Baker, 1970, op. cit., P. 662.

The versions coincide with the events that gave rise to their conceptualization; the volumes are based on logical developmental milestones warranting documentation.

Continued work is planned in using and improving this model. One major activity which MANMODEL will support is the cost-effectiveness analysis efforts associated with the current TOS development. To this end MANMODEL, which now runs in 22K core of memory on the ARI CDC 3300 computer facility, will be installed on a UNIVAC 1108 system to which ARI has time-shared access. The additional memory provided by the 1108 will allow for experimentation toward interfacing MANMODEL with two other models being used in support of the TOS cost-effectiveness analysis--CASE and TOS/SAM. CASE simulates the flow under realistic conditions of multichannel communications traffic through a network of links and nodes. TOS/SAM simulates the hardware and software of the computer, input/output devices, and the communications links within the TOS.

While some preliminary tests of the validity of MANMODEL have been conducted, with satisfying results, further work toward validating this simulator is both warranted and planned.

Possibly more important for scientific psychology are the implications for research from lessons learned during the development of Version III. To elaborate, when MANMODEL is being run as a pure computer simulation (e.g., as Version I or II) handling such sources of variation as motivation, level of aspiration, and stress is not too difficult. The motivational algorithm, for example, is theoretically sound and the outputs behave in a reasonable and expected way.

However, while we were developing Version III of MANMODEL (the man-in-the-loop hybrid simulation version) we were visited by Mr. Brian Venner of the Army Personnel Research Establishment, Farnborough Hants, England. He posed a simple, yet penetrating, question: How do you determine appropriate values for stress tolerance or aspiration level for a subject who is about to be plugged into the MANMODEL simulation loop? To date we do not have a good answer to that question. In a broader sense the question could be addressed to psychology as a whole. How do you integrate knowledge collected independently and in the abstract when the outcome of importance really lies in the interactive effects? We all have heard people speak of "the high expirit de corps of this unit," or "the motivation and morale of that shift is low." We all know and sense it, but how do we measure it? How does one derive a number to represent the motivation for a given subject participating in our hybrid simulation run? Given these numbers, what do they mean? We have discovered that little data exist which bridge the gap between motivation as a psychological concept and concrete implications for human performance in a particular setting.

It should be noted that computerized modelling efforts inherently possess several characteristics relevant to these questions. First, they force one to make the relationships among variables explicit since computers cannot deal with "maybe" statements. Second, because they operate on a GIGO principle--garbage in/garbage out--data deficiencies require immediate and detailed attention. Therefore, the real value of MANMODEL may go beyond its potential contributions to the TOS development effort. It may force us to tackle some of psychology's "fuzzy" questions and, in so doing, may lead us to some interesting answers. Only time and further research will tell whether we will be successful in meeting this challenge.

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CHAPTER I

INTRODUCTION

Prior reports of the series have described the logic and implementation of a digital simulation model for simulating the acts and behaviors of the crew members in the Tactical Operations System (TOS). The first report (Siegel et al., 1973a) presented a description of the stochastic model and the results of initial sensitivity testing and verification. The second report (Siegel et al., 1973b) described extensions of the original model to allow interactivity of the digital computer based model with on line subjects and with an experimenter. The present report describes further extensions which increase its fidelity and utility. The first extension will allow the experimenter to describe the subject's actions not only by recording task related behaviors, but also by identifying and recording up to nine task related actions classified as different types of interruptions. These interruptions are not only identified but are also timed. Task element completion is also identified and recorded by the experimenter. These model extensions result in one additional step towards the fidelity of simulation based on accurate task analytic data as discussed by Baker (1970b).

The second modification allows automatic incorporation of data collected on line into the batch processing model. Customary card supplied, model input data along with interrupt data are modified/replaced by these new data according to specified rules. All other interactive capabilities of the model (for example, task allocation) are retained.

Overview of Extensions

Figure 1 presents an overall view of the new input/output and processing relationships between the hybrid (interactive) model (Siegel et al., 1973b) and the automatic (noninteractive) model (Siegel et al., 1973a) as extended. The hybrid model drives the CRT displays of the subject and experimenter, interprets and shuttles messages from the experimenter to the subject, and records subject responses. Input data from disk or tape, as desired, are provided to the hybrid model. Two sets of output data are provided. One is the standard output, as described in Siegel et al., (1973b), which is recorded on disk and can be run in a batch mode to yield printed output. The second is the subject performance data which are recorded on a disk or tape file. This includes interrupt related data and task performance time data which are then submitted in a batch processing mode to the automatic model. Standard output from the automatic model as described by Siegel et al. (1973a) are also provided by this program.

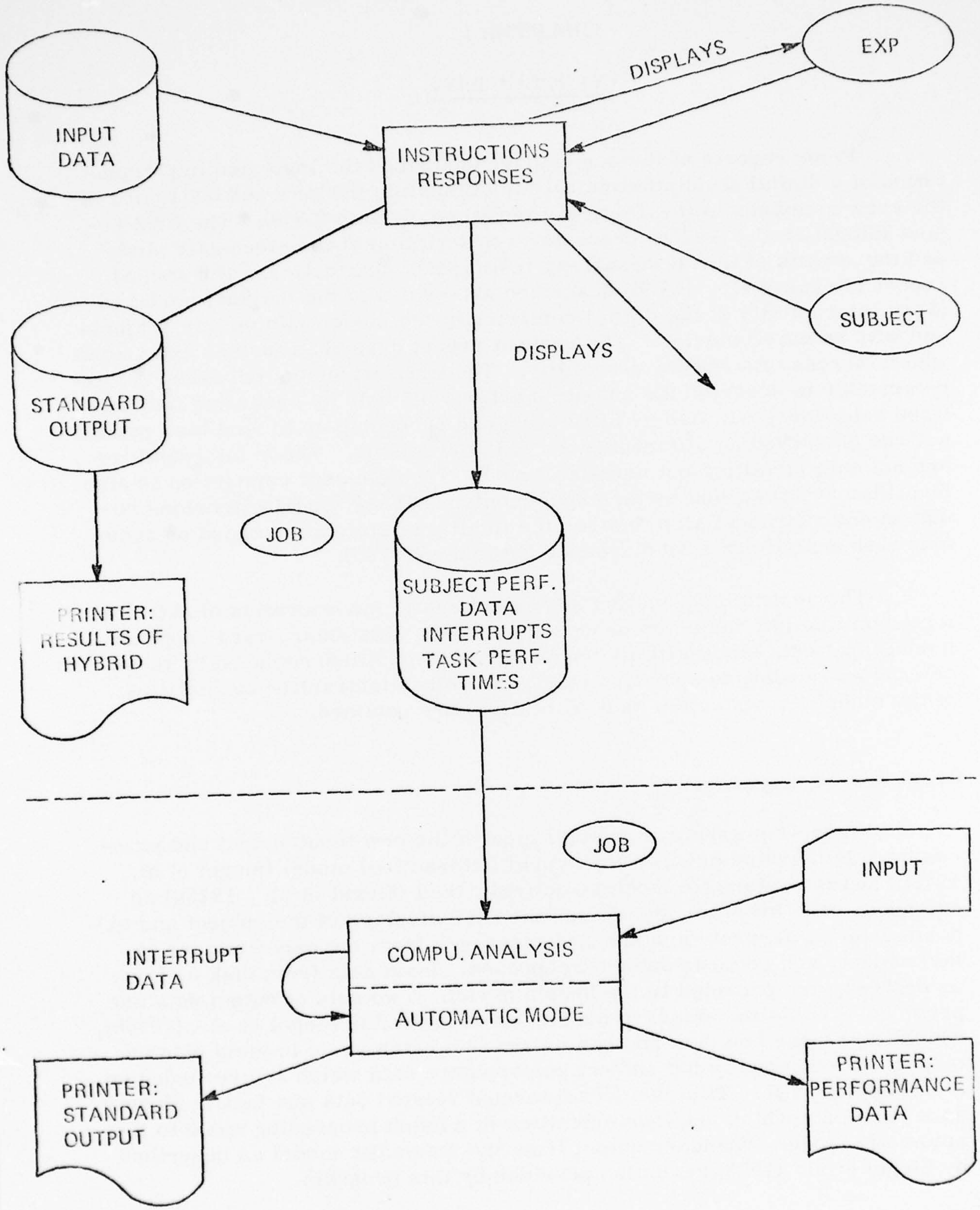


Figure 1. Functional logic.

The Interrupt Variable

Background

In an operational environment, task performance can be expected to be interrupted by either operator (internally) induced or externally induced extraneous activities. These are the types of activities that are usually included under the general rubric of "miscellaneous" in most task analyses. Little effort is usually made to determine their properties and characteristics. The primary reason usually suggested for treating these activities in such a manner is that they are not an element of the actual task. Moreover, they are typically considered "insignificant" and/or unreliable.

Baker (1970b) has provided a framework for task performance tracking in which the concept of an interrupt in an information system can easily be incorporated. His approach was to postulate five "basic and critical" operations that men perform in a message handling system. These are screen, transform, input, assimilate, and decide. The operations are viewed as interrelated along three dimensions: (1) data flow and processing, (2) task analysis for each event in the data flow sequence, and (3) source of variation such as level of training. The first dimension includes the notion of "flowcharting" the sequence of events and/or operations such that start and end points and times are identified. The second dimension investigates "... task-equipment interactions that constitute that portion of the operator's job," while the third dimension refers to sources of variation external to the actual message handling system. The identification and timing of interrupts clearly falls within this model.

Developmental Procedure

Discussions were held with Army Research Institute personnel who possess experience in the operations of the Tactical Operations System to determine the types of interruptions an action officer (AO) or input-output device (IOD) operator might typically encounter in the performance of their respective tasks. The interrupt types were also categorized by these same personnel into five distinct (and, to the extent possible, independent and mutually exclusive) groups. These were:

- intermittent reference interruption
- accidental interruption
- interpersonnel interruption
- personal comfort interruption
- other interruptions

Intermittent reference was defined as job-related information seeking such as referencing glossaries or accessory materials or checks with other personnel for specific message related information. Accidental interruption was defined as disruption due to unforeseen , nonpersonnel related events. This category of interruption includes such items as equipment failure and responses to emergencies.

The third category, interpersonnel interruption, includes disruptions due to person-to-person communication. This category of interruption is exemplified by telephone or other types of conversations which are not job-related. Personal comfort includes interruptions for the operator's personal convenience, such as an unscheduled coffee break.

The final category is intended to include any interruptions not easily placed in any of the four identified categories.

In addition to the development of categories of interruptions, frequency and range (for time) estimates were also obtained from these personnel for each interrupt category.

New Model Logic and Displays

(This section replaces p. 35 (all text after Figure 3-14) and p. 36 (until the paragraph beginning "The display. . . ") in Siegel et al. (1973b).

The display shown in Figure 2 is presented to the experimenter when the subject is to perform a task element. The model will initiate the timing of subject performance of the task element when the experimenter depresses the SEND key.

READY FOR TASK ELEMENT XX OF TASK ANALYSIS X
AT XXXX
DEPRESS SEND KEY WHEN SUBJECT IS READY

Figure 2. Display to experimenter at the beginning of normal task element performance.

The display shown in Figure 3 is presented to the experimenter while the subject is performing a task element. If the experimenter observes the start of an interruption to subject performance, the experimenter enters the proper interrupt code into the display and depresses the SEND key.

O - INTERRUPT CODE (1-9)
DEPRESS SEND KEY WHEN SUBJECT COMPLETES
TASK PERFORMANCE

\- OR -

ENTER PROPER INTERRUPT CODE IN POSITION TWO
AND DEPRESS SEND KEY IF SUBJECT IS INTERRUPTED
DURING TASK PERFORMANCE

Figure 3. Display for indicating interruption of task completion.

The display shown in Figure 4 is presented to the experimenter's CRT immediately after he has indicated a subject interruption. The experimenter may enter a twenty-character description of the interruption. He depresses the SEND key when he observes the completion of the interruption.

```
___ INTERRUPT CODE
ENTER DESCRIPTION BETWEEN /  /  IF DESIRED
/                          /
DEPRESS SEND KEY WHEN INTERRUPTION IS COMPLETED
```

Figure 4. Interruption description display.

In the case of task element type 2, the subject is required to complete a CRT displayed format blank. A new display, as shown in Figure 5, portrays the resulting presentation. In this task type, the experimenter is not allowed to "end" the task element. Only the subject, having completed filling out the CRT provided format, can end the task element by hitting the SEND key.

```
O - INTERRUPT CODE (1-9)
ENTER PROPER INTERRUPT CODE AND DEPRESS SEND KEY
IF SUBJECT IS INTERRUPTED DURING TASK PERFORMANCE
```

Figure 5. Display for indicating interruption while subject is filling out a CRT generated format.

CHAPTER II

INTEGRATION OF INTERRUPT DATA INTO AUTOMATIC MODEL

As noted in Chapter I, a record was written concerning each experimental task performance and interruption which was timed in the hybrid mode. These data, along with card input, are then submitted as a batch processing job to the model in the automatic mode. This chapter details the mathematical operations integrating the required new card input data and task performance and interrupt data(generated in the hybrid mode) with the automatic model. Input/output already considered in the first two reports in this series (noted as "standard" in Figure 1) will not be reviewed.

Figure 6 shows a sample recording of task analytic data which are provided as card input. This figure corresponds to Figure 2-3 in Siegel et al. (1973b) with the addition of data relating to interrupts. Figure 6 identifies which interruption types have nonzero a priori (preset) probabilities of occurring during specific task elements. That is, the analyst identified certain interrupt types as having a nonzero probabilities of occurrence during specific task elements and for those he also provided mean duration and standard deviation (in seconds) estimates.

Figure 7 shows the results of the experimenter's recording of additional interrupts which occurred during a hybrid simulation and identifies when and what types of interruptions occurred. The interrupt sequence and the duration of each interruption is noted, along with the description provided by the experimenter while he was observing the subject at the time that the interruption occurred.

Figure 8 shows collected data for task performance (exclusive of interrupt time) by task element. The heading "order" indicates the order in which the data were collected.

Figure 9 shows the mean duration of each type of interrupt for each task analytic element for task analysis 1. Similar data are provided for each task analysis. Entries represent mean weighted interrupt times and are employed as input to the automatic model. They are calculated for each interrupt as follows:

If ten or fewer interrupts of a given type were observed during data collection (within each task analysis and for each task element)

$$\text{Weighted Mean Interrupt Time} = [\,(\text{Total interrupt time}) + (\text{Preset mean interrupt time}) \times (10 - \text{Number of interrupts})]\,/\,10$$

TASK ANALYTIC DATA

TASK	ELEMENT	TYPE	CRITICAL	SEGMENT	NEXT-FAIL	NEXT-SUCC	MEAN-TIME	SIGMA	PROBABILITY	UNDETECTED-ERROR TYPE	PROB
1											
	1	0	C	3	1	2	15.00	4.00	.990		0
	INTERUPTION TYPE	1	PROBABILITY=	1.000	MEAN DURATION=		10.0	SD=	1.5		
	2	0		0	2	3	12.00	2.50	.900		0
	3	0		0	3	4	12.00	2.50	.900		0
	INTERUPTION TYPE	1	PROBABILITY=	.400	MEAN DURATION=		7.4	SD=	.7		
	INTERUPTION TYPE	2	PROBABILITY=	.700	MEAN DURATION=		30.0	SD=	3.5		
	4	2	C	0	5	5	3.09	.50	1.000	T	0
	5	0	C	0	6	6	10.00	2.00	.600		0
	6	0		0	5	7	15.00	2.70	.600		0
	7	0	C	4	7	0	5.00	1.50	1.000		0
2											
	1	0		5	1	2	7.00	1.50	.990		0
	2	0	C	6	2	3	5.00	1.00	.900		0
	3	4		0	4	4	.30	.02	1.000		0
	4	2	C	0	5	5	2.37	.47	1.000		0
	5	0		0	5	6	12.00	3.00	.700		0
	6	0	C	7	6	0	4.20	1.20	1.000		0

Figure 6. Sample input task analytic data.

INTERRUPTION DATA IN ORDER OF OCCURRENCE

SEQ	TASK/ELEMENT	MSG NO	DURATION	TYPE	DESCRIPTION
1	2/ 1	1	60	1	LITE CIG;
2	2/ 1	1	17	3	CONV;
3	2/ 4	1	61	0	CURSE:
4	2/ 1	2	33	1	CONVERSATION;
5	2/ 4	2	6	0	
6	2/ 4	2	17	1	TELEPHONE;
7	2/ 4	2	2	0	
8	2/ 4	2	2	0	
9	2/ 4	2	4	0	

Figure 7. Sample interrupt data.

COLLECTED TIME DATA IN SEQUENCE

ORDER	TASK/ELEMENT	DURATION
1	2/ 1	181
2	2/ 4	65
3	2/ 1	120
4	2/ 4	58
5	2/ 4	13

Figure 8. Sample collected data.

INTERRUPTION DATA FOR TASK ANALYSIS 1

TASK ELEMENT	INTERRUPTION CATEGORY 1	2	3	4	5	6	7	8	9
1	10.0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	7.4	30.0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0

DATUMS ARE MEAN DURATIONS OF INTERRUPTS

Figure 9. Sample integration of interrupt time data.

If more than ten interrupts of that type were observed within a given task analysis and for each task element, then the mean data from data collection completely replaces the preset values.

Calculations for probability of occurrence of each interrupt type/ task analysis/ task element are similarly computed and printed in tables such as shown in Figure 10. These (new) probabilities are also provided as input to the automatic model. Thus, if sufficient data have been collected, preset values are completely ignored. If insufficient data are available, a weighting scheme is employed where the impact of collected data on the final values employed are a function of their stability.

Figure 11 presents a sample of the task element means and standard deviations (repeated for each task analysis) provided as input to the automatic model. Preset values are employed unless data have been obtained using the hybrid mode. Then, the mean of the collected data is substituted for the preset values giving new values to the task elements of the task analyses which reflect subject data.

Figure 12 parallels Figure 2-5 in Siegel et al., 1973b, with the addition of interrupt durations and types. The interrupt times, together with the task performance times, are included in the cumulative time.

INTERRUPTION DATA FOR TASK ANALYSIS 1

TASK ELEMENT	INTERRUPTION CATEGORY 1	2	3	4	5	6	7	8	9
1	1.000	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	.400	.700	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0

DATUMS ARE PROBABILITIES OF OCCURRENCE

Figure 10. Sample integration of interrupt probability data.

	ELEMENT	MEAN	SD
TASK 1	1	15.000	4.000
	2	12.000	2.500
	3	12.000	2.500
	4	3.090	.500
	5	10.000	2.000
	6	15.000	2.700
	7	5.000	1.500
	8	0	0
	9	0	0
	10	0	0

Figure 11. Sample task element data.

MESSAGE NUMBER	3	MAN	AO-1	DAY	11
MESSAGE TYPE	AUD	STRESS FACTOR	1.00	HOUR	1
MESSAGE ORDER	3	FATIGUE	1.00	ITERATION	1
		ASPIRATION	.97		
		CUM. IDLE	0		

MESSAGE ARRIVAL	0
MESSAGE START	579.7

ELEMENT NO.	EXECUTION TIME	CUMULATIVE TIME	OUTCOME (SFR)	TYPE OF ELEMENT	CRITIC -ALITY	SEGMENT ENDED	ERROR TYPE	ERROR RETURNS		INTRP
1	16.95	608.75	S	0	C	3		1	12.07	1
2	6.98	615.73	S	0		0		2	0	0
3	7.49	647.43	S	0		0		3	24.21	2
4	20.09	667.52	S	2	C	0	T	3	0	0
5	12.54	680.06	F	0	C	0		3	0	0
6	15.34	695.40	S	0		0		4	0	0
7	4.99	700.40	S	0	C	4		5	0	0

MESSAGE 3

PROCESSED BY AO-1
TRANSFORM ERRORS

COMMISSION	0
ABREV TYPO/SPAC	0
OMISSION	0
OTHER ERRORS	0

TOT. UNDET. ERRORS	0
NO. ERROR RETURNS	5
INFORMATION LOSS	0

Figure 12. Sample detailed message processing output.

CHAPTER III

DISCUSSION

The inclusion of data collection concerning interrupts represents a step in increasing the fidelity of the computer simulation of operator performance in the TOS system. Too often "extraneous" events (which we have categorized here as interrupts) are ignored with little effort being made at their identification and quantification. As such, any predictable regularities with respect to their type and magnitude are lost leading to a greater degree of unpredictable variance than might otherwise be present when simulating task performance. The simple fact that categories for interruptions, independent of actual task elements, were developed without great difficulty suggests that some regularities in these "extraneous" events can be quantified.

The second major addition to what will be referred to henceforth as the MANMODEL is the ability to collect data in an interactive mode using any combination of real and simulated subjects and then immediately simulate (in an automatic mode) the entire interactive process. An experimenter can thus employ real subjects for data collection and then almost immediately simulate the entire message handling procedure. This procedure allows him the ability to manipulate variables during data collection and then by using the automatic mode of the MANMODEL to measure effects using this "new" message handling procedure. Different system configurations based on actual data can thus be manipulated with their effects becoming almost immediately apparent.

As sensitivity analyses have already been completed, a logical next step in the development of the MANMODEL would be a validation of the model's predictions. Full confidence cannot be placed in the techniques and logic employed in the model until one or more empirical validations have taken place. These validations might take the form of having teams of operators perform for a specified period in a TOS-type message handling system. Alternative teams would experience different types of messages or the same types under different types of circumstances (for example, more interrupts). Model predictions might then be validated against obtained data possibly by using the statistical procedure developed by Siegel et al. (1972).

REFERENCES

Baker, J.D. *Acorns in flower pots/psychologists in the field.* Paper presented at the United States Army Human Factors Research and Development Sixteenth Annual Conference, El Paso, Texas, October 1970. (a)

Baker, J.D. Quantitative modeling for human performance in information systems. *Ergonomics,* 1970, *13,* 645-664. (b)

Baker, J.D., Mace, D.J. & McKendry, J.M. *The transform operation in TOS: Assessment of the human component.* BESRL Technical Research Note 212,AD697716, 1969.

Siegel, A.I., Lautman, M.R., & Wolf, J.J. *A Multimethod-multitrait validation of a digital simulation model.* Wayne, Pa.: Applied Psychological Services, 1972.

Siegel, A.I., Wolf, J.J., & Leahy, W.R. *A digital simulation model of message handling in the Tactical Operations System: The model, its sensitivity and user's manual.* U.S. Army Research Institute: Research Memorandum 73-5, 1973. (a)

Siegel, A.I., Wolf, J.J., Leahy, W.R., & Bearde, J.L. *A digital simulation model of message handling in the Tactical Operations System: Extensions of the model for interactivity with subjects and experimenters.* U.S. Army Research Institute: Research Memorandum 73-6,1973. (b)

APPENDIX A

Additions and Modifications to the Interactive TOS Model for Interrupt Consideration

The modifications noted below should be made in the report: *A Digital Simulation Model of Message Handling in the Tactical Operations System: II. Extensions of the Model for Interactivity with Subjects and Experimenters* by Arthur I. Siegel, J.J. Wolf, W.R. Leahy, and J.L. Bearde. References to pages deleted will refer to that report.

Control Cards for Automatic Model

1. Sequence card (this card and all others here listed have a 7 and a 9 in column 1
2. Job card
3. FET,CECIL,OVERLAYS,,,
4. MODIFY,,,NEWFET
5. FET,CECIL,OVERLAYS,512,,,
6. OPEN,25
7. FET,TEMP,SCRATCH1,,,
8. MODIFY,,,NEWFET
9. FET,TEMP,SCRATCH1,256
10. OPEN,3
11. EQUIP,01=60,02=61,10=MT
12. LOAD,10
13. RUN
14. data
15. end of file

These control cards allocate the disk file OVERLAYS (owner CECIL) to logical unit 25 and disk file SCRATCH1 (owner TEMP) to logical unit 3. Within the program, logical unit 25 is used to store the overlays while logical unit 3 is assumed to hold experimentally collected task duration and interruption data. The control cards also assume that the program is stored in binary form on magnetic tape.

The control cards to store the program on tape are:

1. Sequence card
2. Job card
3. EQUIP,10=MT
4. XFER,10
   binary cards
5. CTO,END
6. End of file
7. End of file

p. A-2 (Table 1) Insert:

Variable	*Subscript FORTRAN*	*Maximum Value*	*Maximum Value FORTRAN*
Interruption Category			
1- Intermittant reference	ITY	9	ITYMAX
2- Accidental interruption			
3- Personal comfort			
4- Other			

NOTE: Interruptions can be assigned for a maximum of 3 task analyses and 10 task elements.

p. A-5 (Table A-3) Replace ORO (8)- Not used................17
with

ORO (8)--Output reading option 8
If equal to 1 read in experiment data and complete interruption trials and new task analysis....17

p. A-10 (Table A-8) Add:

INTS	Number of interruptions to be considered on this task element. This value determines the number of interrupt data to be read in (INTS $\leq$ 4 read 1 additional card: 5 $\leq$ INTS $\leq$ 9 read 2 additional cards)	80
ITYP	Type of interruption, up to four on a card	2,22,42,62
PROBI(I,K,ITYP)	Probability of this type of interrupt	3-8,23-28 43-48,63-68,
AITE(I,K,ITYP)	Average duration of interrupt	9-14,29-34 49-54,69-74
ADI(I,K,ITYP)	Standard deviation of interruption	15-20,35-40 55-60,75-80

p. A-12 (Table A-10) Add:

NDCI(I,K,ITY)	Number of interrupts of type ITY on task element I for analysis K
NDC(I,K)	Number of experimental performance times collected for task element I of task analysis K
DCITOT(I,K,ITY)	Sum of performance times for interrupts
DCTOT(I,K)	Sum of performance times for task elements

p. A-13 (Table A-10) Add to the nondimensioned variables:

NINTS	Total number of interruptions recorded
NOPTI	Total number of experimental task performance times recorded
NCHARS	Total number of characters in messages which were experimentally performed
TMIN	Duration of interrupt

p. A-14 (Table A-11) Add:

COMPU	Computation	Computes interruption and new task analysis data.

p. B-2 Before last paragraph add:

The experimenter is also given the capability to indicate the interruption of subject performance after the subject has begun task performance. Interruption codes of 1 through 9 are used to classify the interruptions and the experimenter can enter an additional 20 character description of each interruption.

p. B-3 Before *supporting subroutines* add:

The experimenter indicates task performance start time and all interruptions in this mode of operation. The completion of a task is indicated when the subject depresses the SEND key after entering the TOS data.

In either case, of subject performance the model will write to a disk file interruption and task performance data to be processed by an analysis program in the foreground mode. If this option is selected, incorrect subject responses are not displayed to the experimenter.

p. B-4 Add:

ORO(8) - Option to write interrupt and task performance data to a disk file for later processing. (Set to 1 to exercise option)

INTRY(1-10) - Array used to write interruption data and task performance data to disk for later processing.

p. B-6 Add:

NINTK=	Total interrupt time (in seconds) for a task performance
NOPTI=	Total number of task elements by subjects
ISCI=	Mode indicator for CRT management routine (WDISP) 0: WDISP WAITS FOR SEND KEY FROM ONE CRT. 1: WDISP WAITS FOR SEND KEY FROM EITHER EXPERIMENTER OR SUBJECTS CRT. 2: WDISP DOES NOT WAIT FOR SEND KEY WDISP SETS ISCI TO CRT NUMBER FROM WHICH SEND KEY WAS RECEIVED
ISCRNE=	IDENTIFIER OF EXPERIMENTER CRT
IEXM=	Mode indicator for experimenter 0: No interrupt is outstanding 1: Interrupt is outstanding
KT=	Interrupt code
IDUR=	Duration of current interrupt

p. B-7 Add after card 3 ($^{7}_{9}$ Open,2):

$^{7}_{9}$ FET,TEMP,SCRATCH1,,,

$^{7}_{9}$ MODIFY,,,NEWFET

$^{7}_{9}$ FET,TEMP,SCRATCH1,256

$^{7}_{9}$ OPEN,3

p. B-13 Change 16-18 3x not used to

16	IX	Not used
17	I1	ORO(8)--if 1 write interruption and task performance on disk
18	1X	not used

p. B-22 Add:

P. B-22 Add:

If the option to write interruption and task performance data to disk is selected, then that data will be entered onto the disk reserved for the interactive model. This same disc must be mounted when the batch model is executed to process the recorded data.

APPENDIX B

Revised Flow Charts for MANMODEL

The flow charts presented in Appendix B represent modifications to prior flow charts as a consequence of the revisions described in the body of this report.

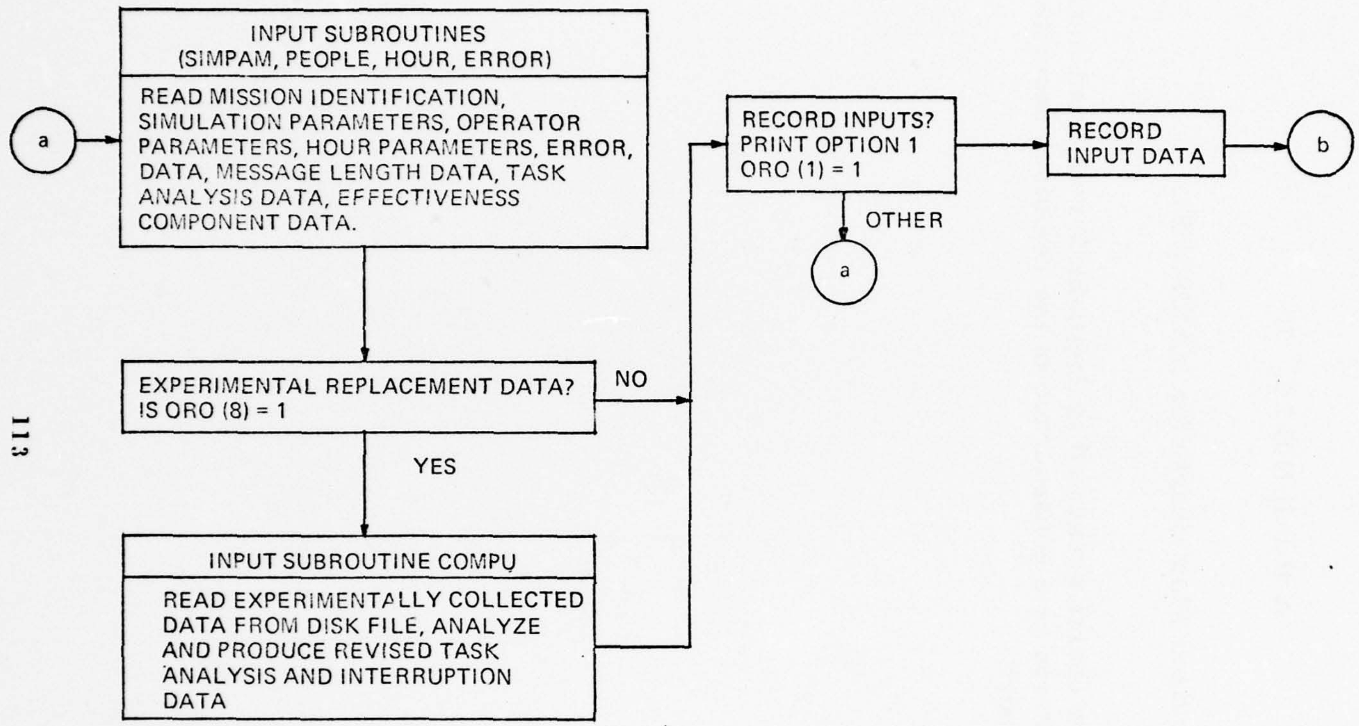
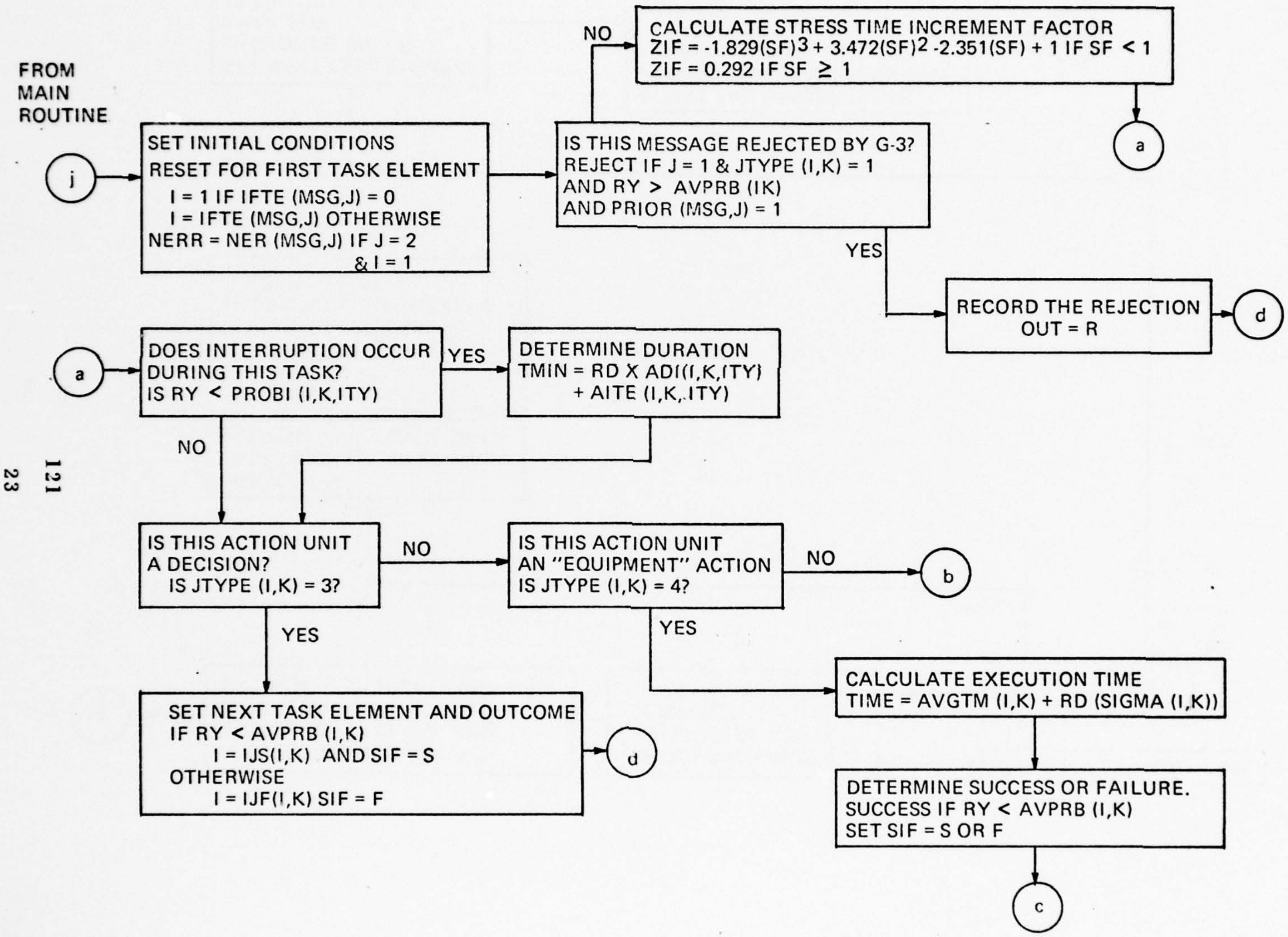


Figure B-1. Main sequence logic flow for TOS model (Routine Sips)



Operator processing subroutine (Routine Proc)

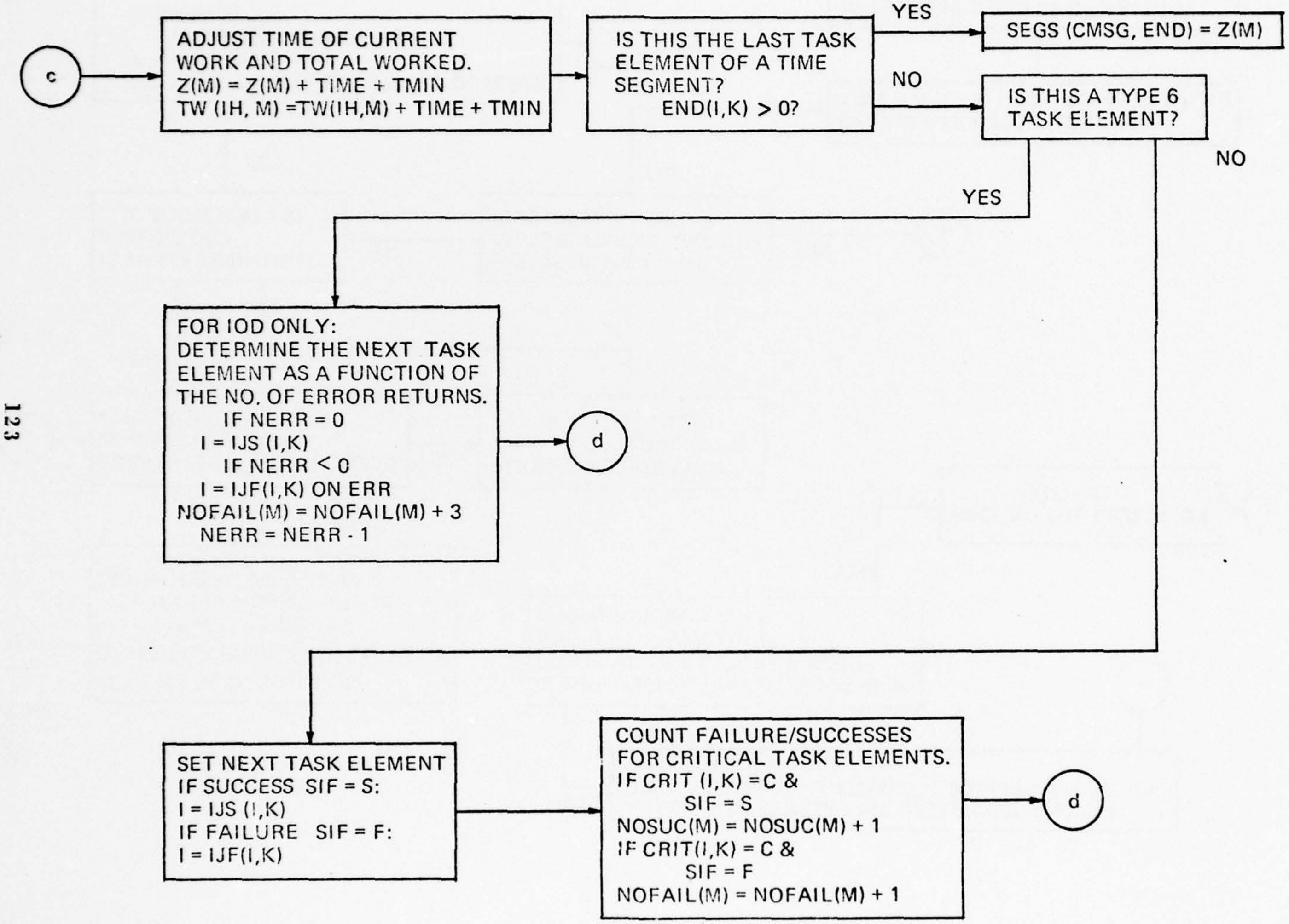


Figure B-2 (Cont.)

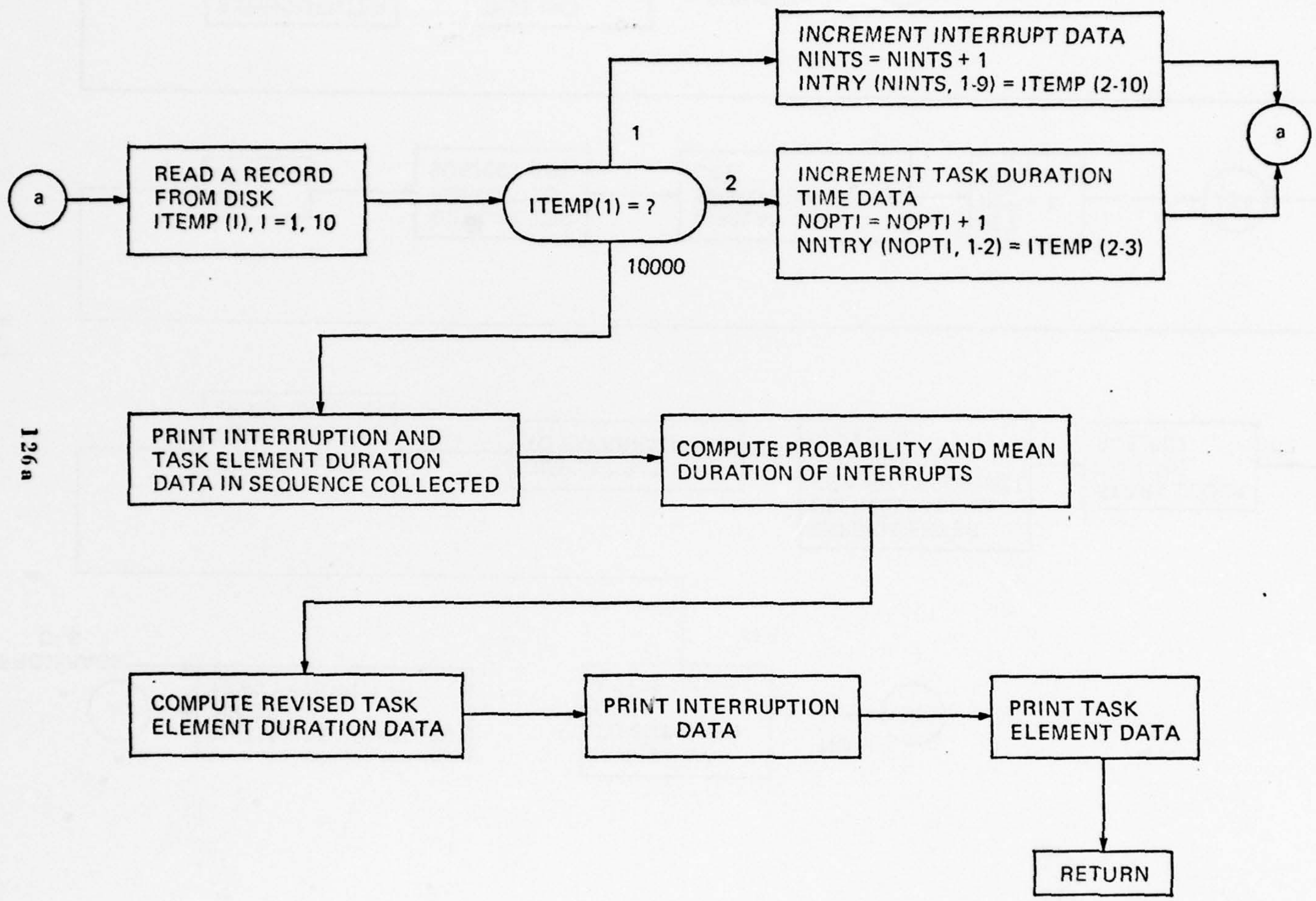
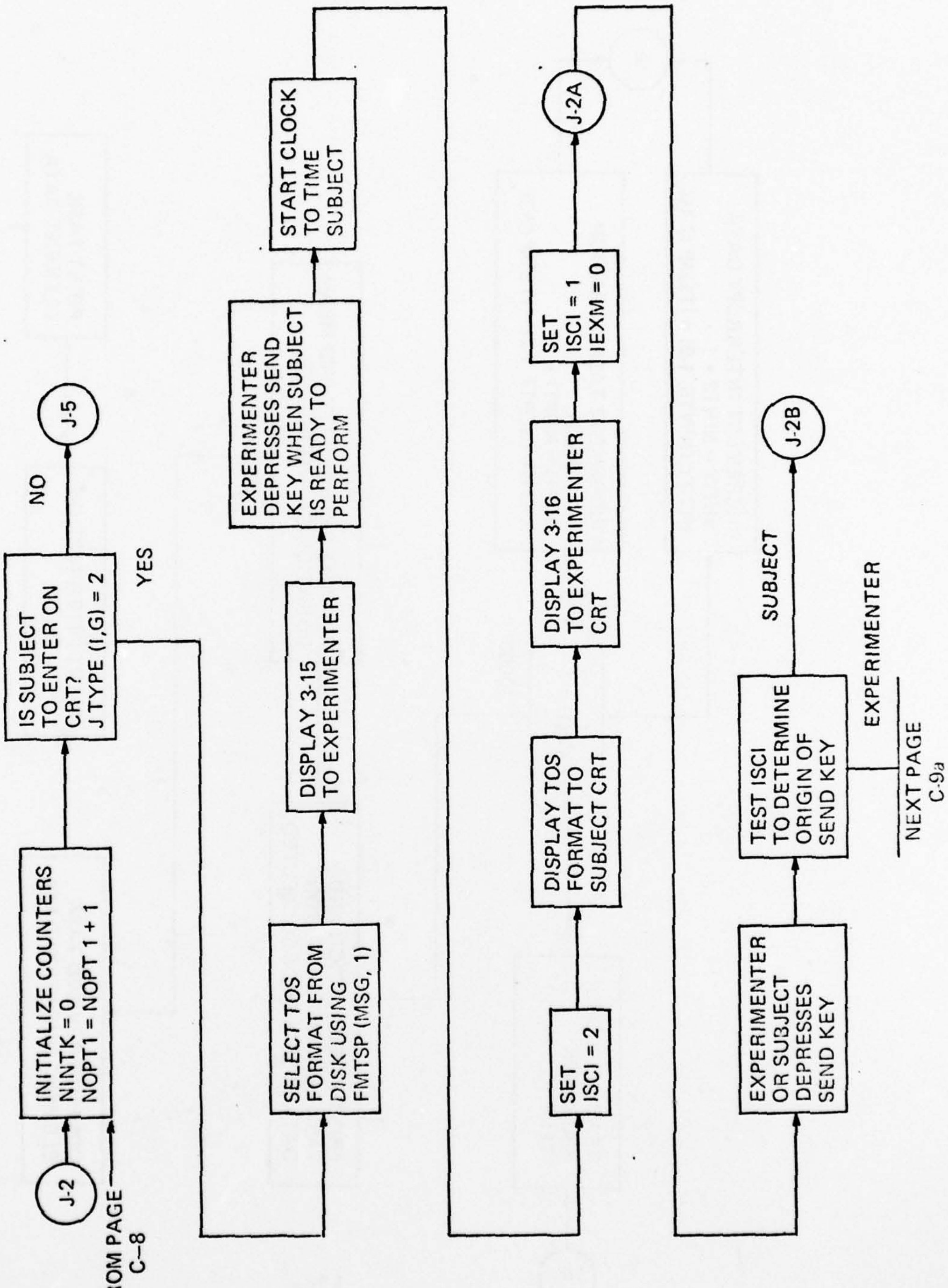
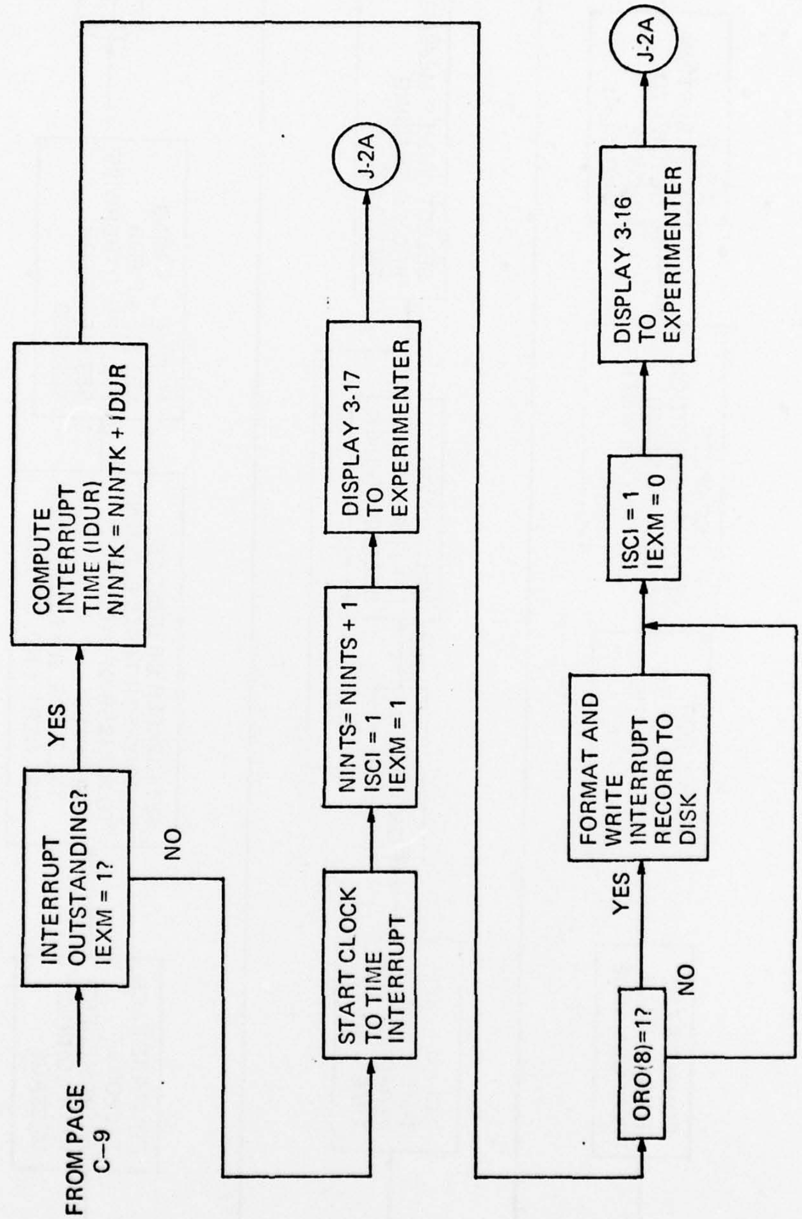
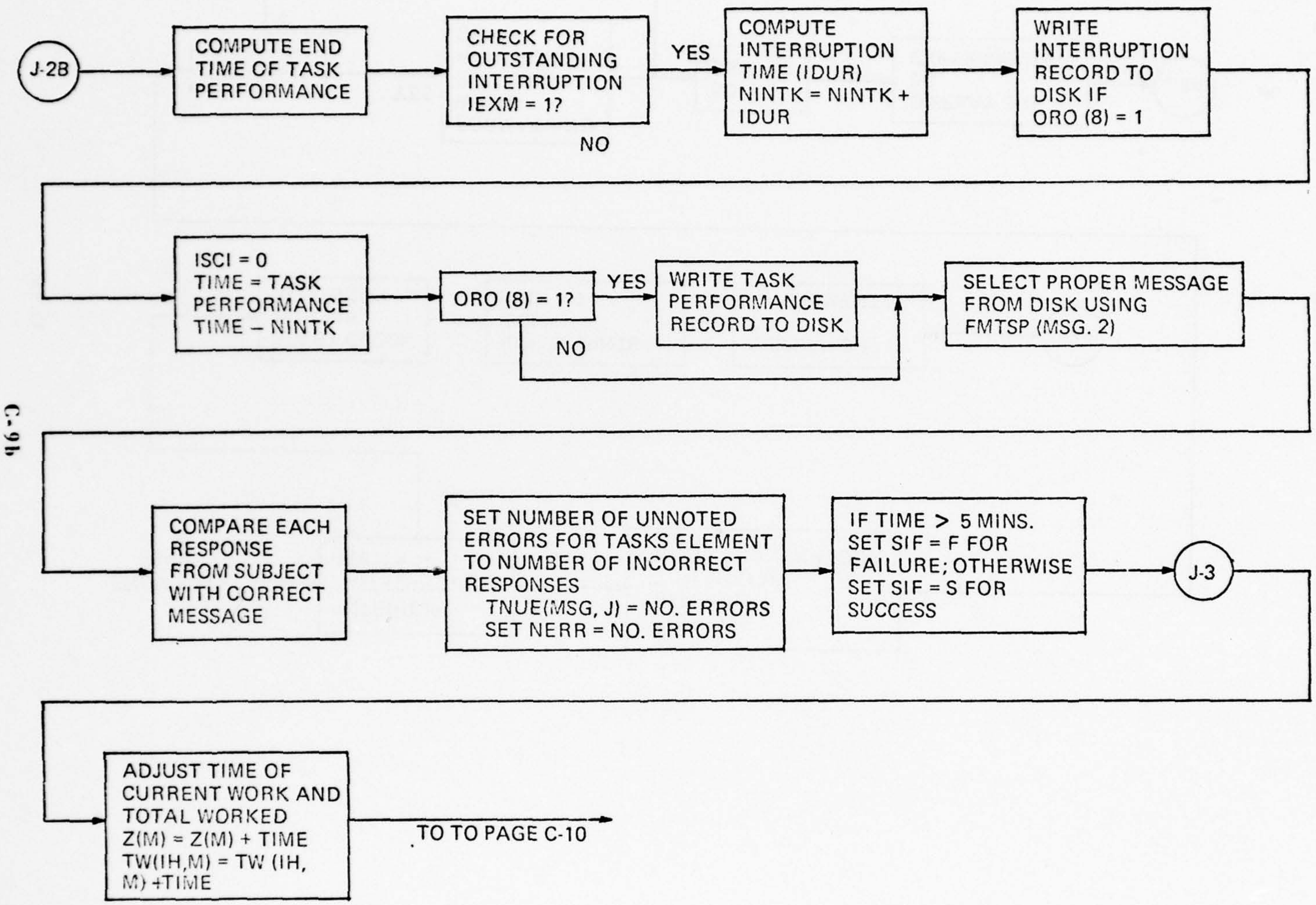


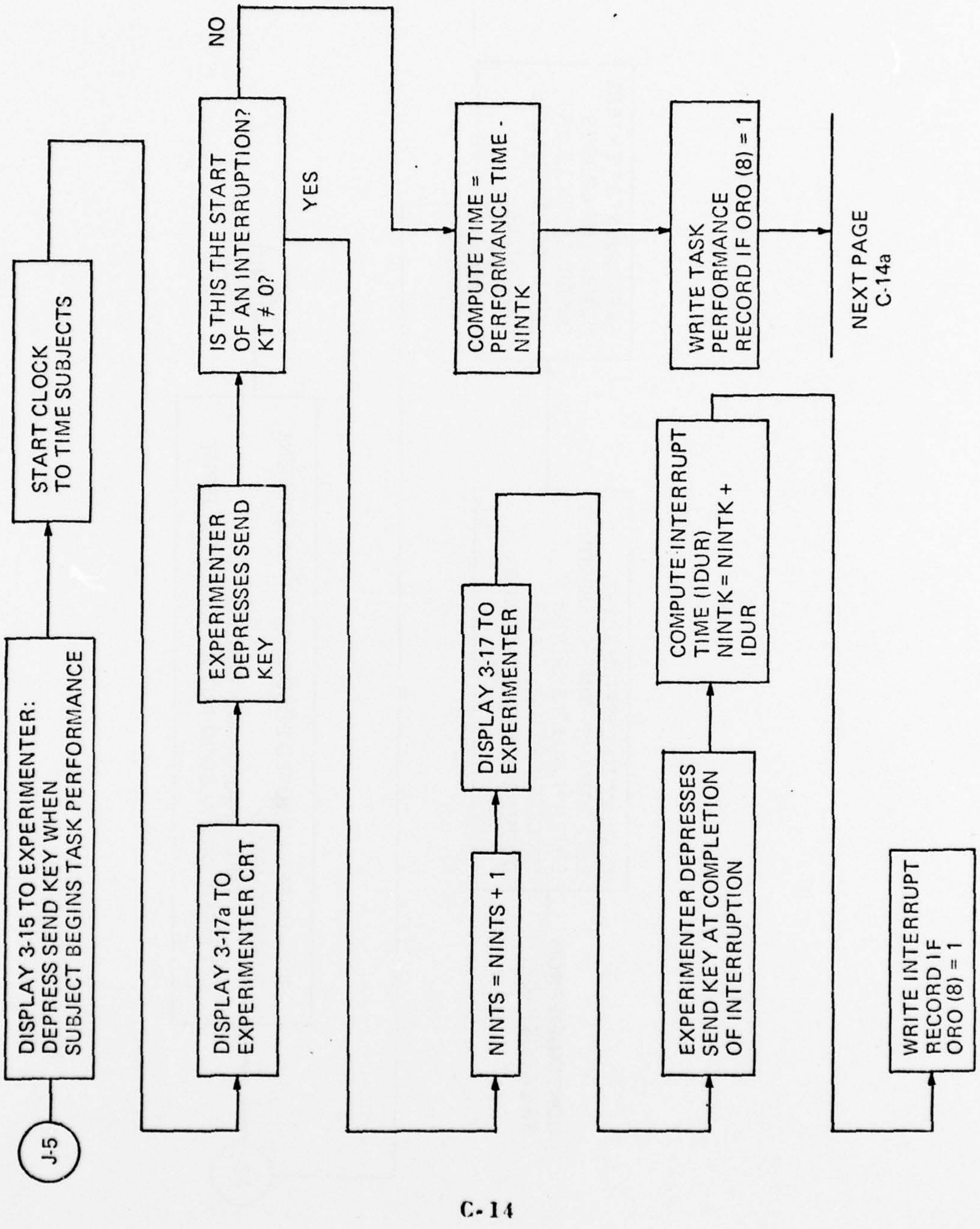
Figure B-5. Computational subroutine (COMPU)


J-2
FROM PAGE C–8
INITIALIZE COUNTERS
NINTK = 0
NOPT1 = NOPT 1 + 1
IS SUBJECT TO ENTER ON CRT?
J TYPE (I,G) = 2
NO
J-5
YES
SELECT TOS FORMAT FROM DISK USING FMTSP (MSG, 1)
DISPLAY 3-15 TO EXPERIMENTER
EXPERIMENTER DEPRESSES SEND KEY WHEN SUBJECT IS READY TO PERFORM
START CLOCK TO TIME SUBJECT
SET ISCI = 2
DISPLAY TOS FORMAT TO SUBJECT CRT
DISPLAY 3-16 TO EXPERIMENTER CRT
SET ISCI = 1 IEXM = 0
J-2A
EXPERIMENTER OR SUBJECT DEPRESSES SEND KEY
TEST ISCI TO DETERMINE ORIGIN OF SEND KEY
SUBJECT
J-2B
EXPERIMENTER
EXPERIMENTER
NEXT PAGE C-9a

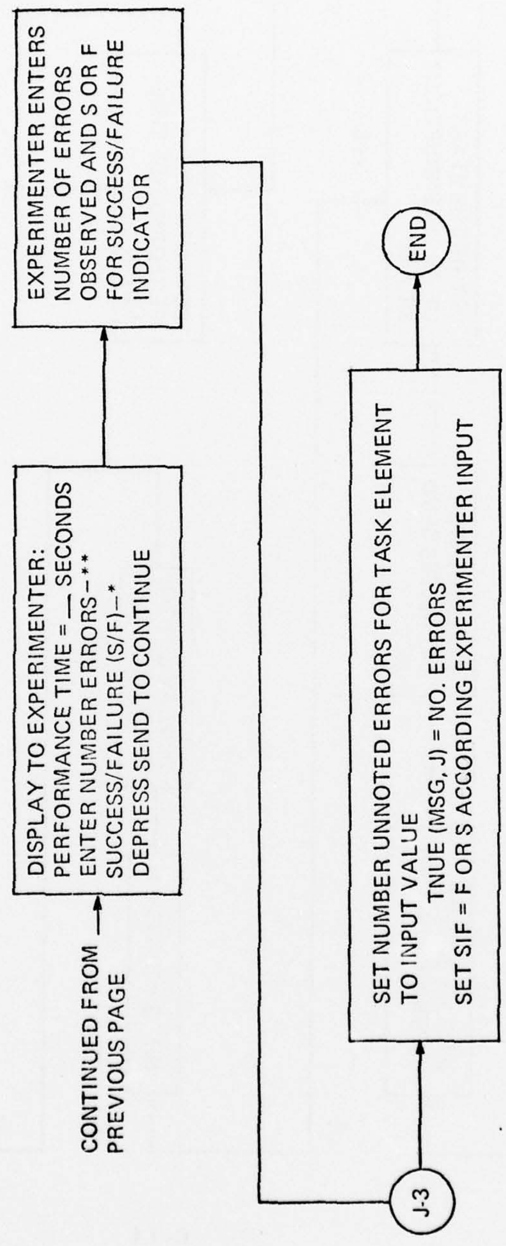


FROM PAGE C–9
INTERRUPT OUTSTANDING? IEXM = 1?
YES
NO
COMPUTE INTERRUPT TIME (IDUR) NINTK = NINTK + IDUR
START CLOCK TO TIME INTERRUPT
NINTS= NINTS + 1 ISCI = 1 IEXM = 1
DISPLAY 3-17 TO EXPERIMENTER
J-2A
ORO(8)=1?
YES
NO
FORMAT AND WRITE INTERRUPT RECORD TO DISK
ISCI = 1 IEXM = 0
DISPLAY 3-16 TO EXPERIMENTER
J-2A


J-2B
COMPUTE END TIME OF TASK PERFORMANCE
CHECK FOR OUTSTANDING INTERRUPTION IEXM = 1?
YES
NO
COMPUTE INTERRUPTION TIME (IDUR) NINTK = NINTK + IDUR
WRITE INTERRUPTION RECORD TO DISK IF ORO (8) = 1
ISCI = 0 TIME = TASK PERFORMANCE TIME – NINTK
ORO (8) = 1?
YES
NO
WRITE TASK PERFORMANCE RECORD TO DISK
SELECT PROPER MESSAGE FROM DISK USING FMTSP (MSG. 2)
COMPARE EACH RESPONSE FROM SUBJECT WITH CORRECT MESSAGE
SET NUMBER OF UNNOTED ERRORS FOR TASKS ELEMENT TO NUMBER OF INCORRECT RESPONSES TNUE(MSG, J) = NO. ERRORS SET NERR = NO. ERRORS
IF TIME > 5 MINS. SET SIF = F FOR FAILURE; OTHERWISE SET SIF = S FOR SUCCESS
J-3
ADJUST TIME OF CURRENT WORK AND TOTAL WORKED Z(M) = Z(M) + TIME TW(IH,M) = TW (IH, M) +TIME
TO TO PAGE C-10



J-5
DISPLAY 3-15 TO EXPERIMENTER: DEPRESS SEND KEY WHEN SUBJECT BEGINS TASK PERFORMANCE
START CLOCK TO TIME SUBJECTS
DISPLAY 3-17a TO EXPERIMENTER CRT
EXPERIMENTER DEPRESSES SEND KEY
IS THIS THE START OF AN INTERRUPTION? KT ≠ 0?
NO
YES
COMPUTE TIME = PERFORMANCE TIME - NINTK
WRITE TASK PERFORMANCE RECORD IF ORO (8) = 1
NEXT PAGE C-14a
NINTS = NINTS + 1
DISPLAY 3-17 TO EXPERIMENTER
EXPERIMENTER DEPRESSES SEND KEY AT COMPLETION OF INTERRUPTION
COMPUTE INTERRUPT TIME (IDUR) NINTK = NINTK + IDUR
WRITE INTERRUPT RECORD IF ORO (8) = 1


CONTINUED FROM PREVIOUS PAGE
DISPLAY TO EXPERIMENTER:
PERFORMANCE TIME = __ SECONDS
ENTER NUMBER ERRORS—**
SUCCESS/FAILURE (S/F)—*
DEPRESS SEND TO CONTINUE
EXPERIMENTER ENTERS NUMBER OF ERRORS OBSERVED AND S OR F FOR SUCCESS/FAILURE INDICATOR
J-3
SET NUMBER UNNOTED ERRORS FOR TASK ELEMENT TO INPUT VALUE
TNUE (MSG, J) = NO. ERRORS
SET SIF = F OR S ACCORDING EXPERIMENTER INPUT
END